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The critical role of CCS and EOR in managing US carbon emissions

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CO_2 Summit II: Technologies and Opportunities

Santa Ana Pueblo, New Mexico, USA

GREAT PLAINS INSTITUTE

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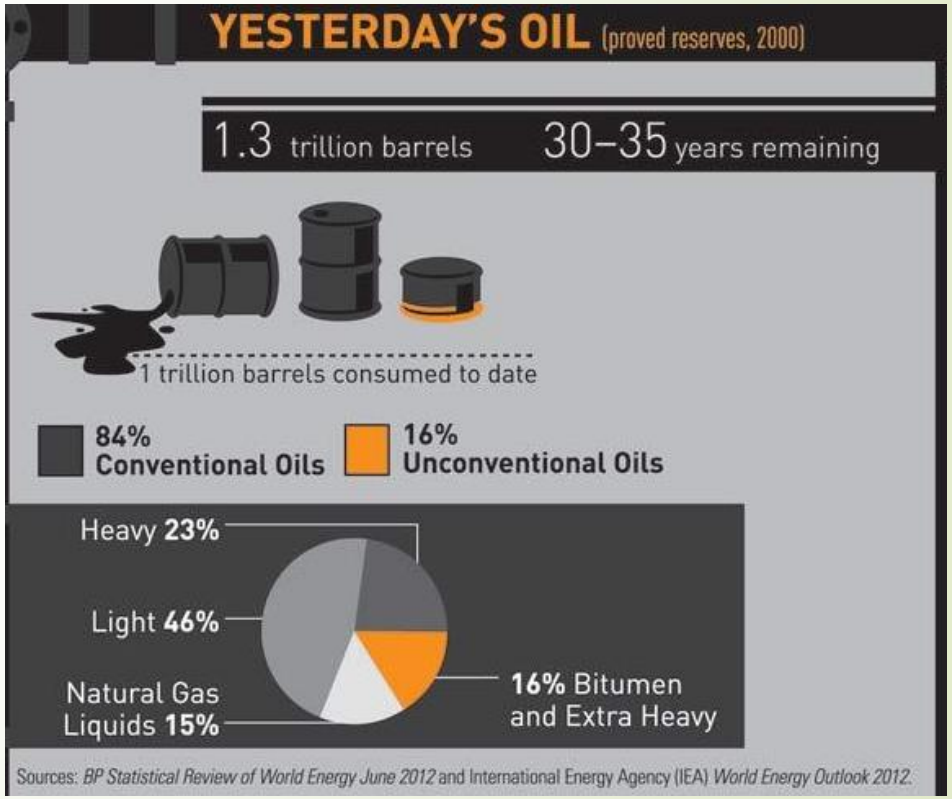
Overview

- Essential Role of CCS in Carbon Mitigation
- Evolution and Potential of CO2-EOR as a Proven Commercial CCS Pathway
- Need and Growing Support for Incentives to Spur Commercial Project Deployment and Bring Down Costs
- Relative Cost of CCS Incentives Compared to Comparable Federal Policies and Their Potential to Generate Net Federal Revenue
- Growing Role of the States in Supporting Incentives Policy

Mounting Climate Concerns and Unconventional Oil and Gas Development have Transformed the Energy Landscape and Environmental Debate

A Decade Ago:

- Concerns over peak oil.
- Accelerating global demand for oil + slow growth in proved reserves = looming energy insecurity.
- U.S. environmental debate focused primarily on future of coal.



Source: Deborah Gordon, Carnegie Endowment.

Today: The End of Scarcity

Horizontal Drilling/ Hydraulic Fracturing Innovation

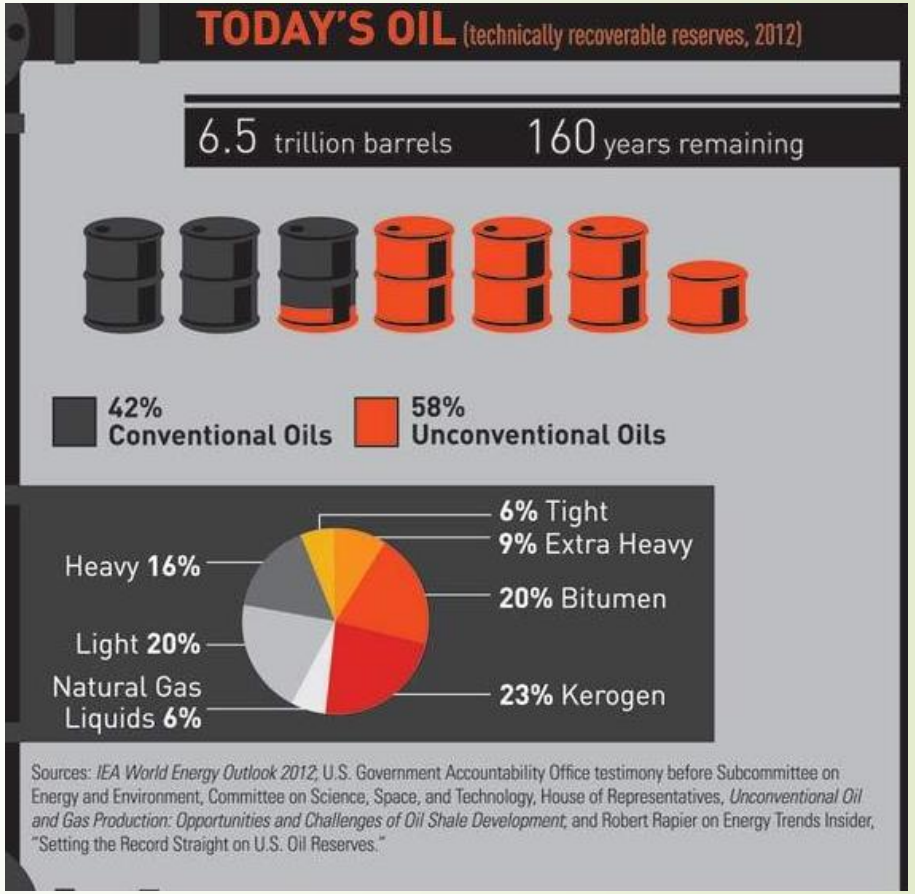
+

Permissive regulation of private lands drilling

→ Transformation of American energy & economic prospects

+

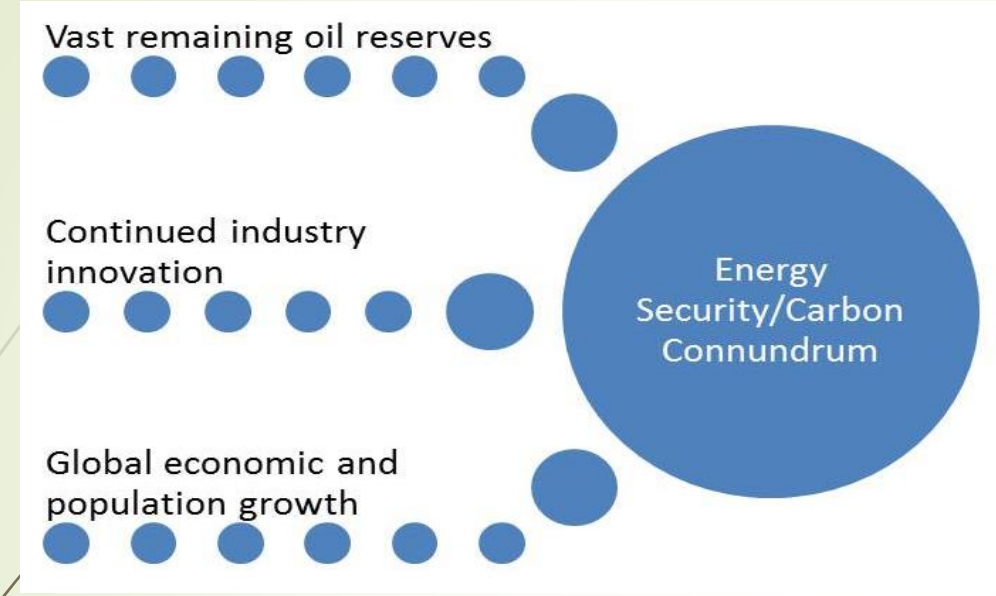
Increased federal energy efficiency requirements



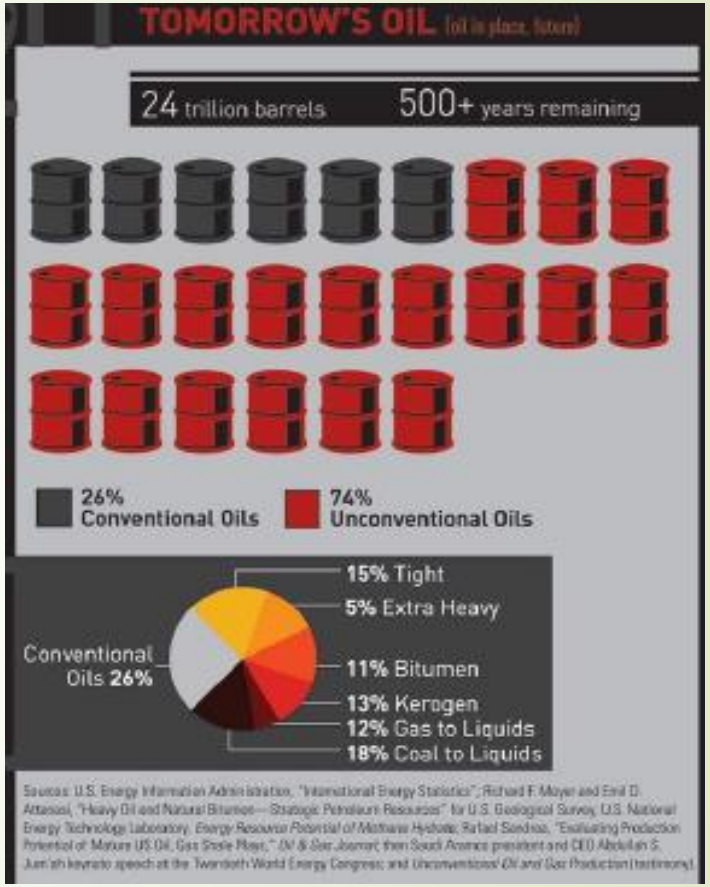
Source: Deborah Gordon, Carnegie Endowment.

Environmental and climate activism has expanded from stopping coal to opposing unconventional oil and gas (hydraulic fracturing, Keystone XL, divestment campaigns, etc.)

The Future: Energy Security Opportunity and Carbon Challenge



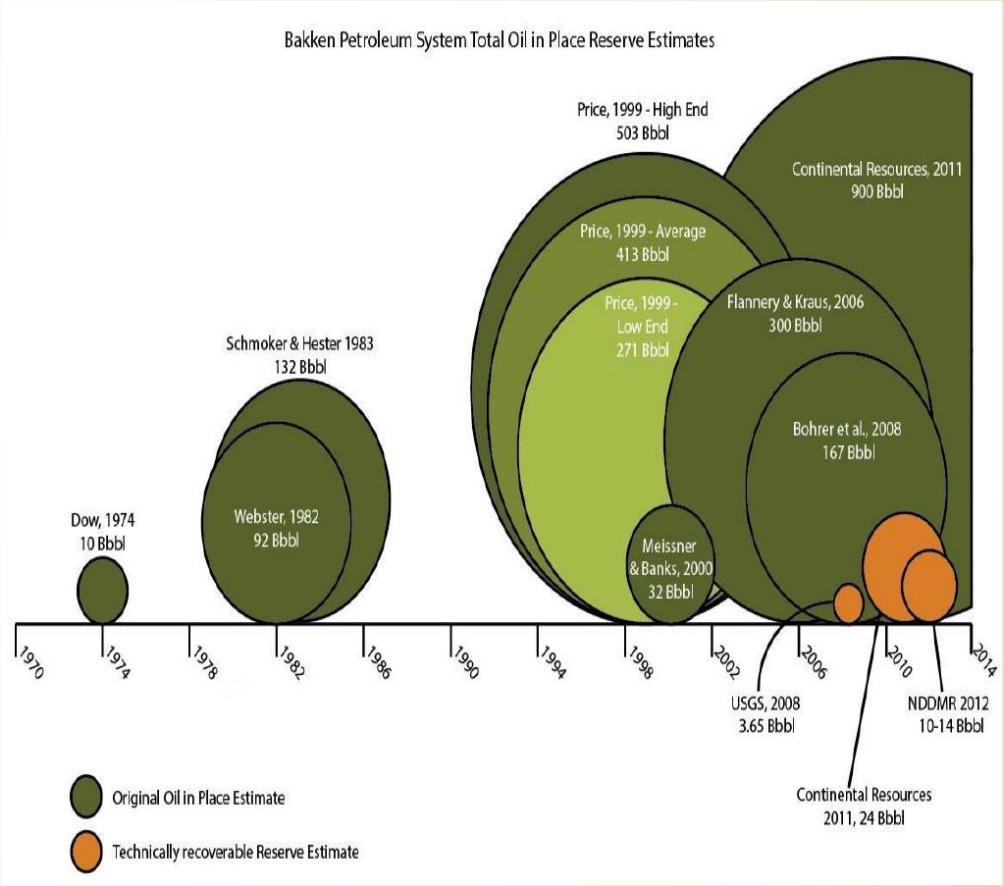
- Remaining coal, oil, natural gas and other hydrocarbon reserves contain far more carbon than can be released and still stabilize future levels of atmospheric CO_2 . . . **IF** produced and used in conventional ways.
- Increasingly polarized national environmental debate—business as usual vs. keep it in the ground—risks gridlock and poor outcomes for industry and environmental advocates alike.



Source: Deborah Gordon, Carnegie Endowment.

The Bakken: A Microcosm of Our Broader Energy Security and Carbon Challenge

- Projections of hundreds of billions barrels of oil in the Bakken alone—just one major unconventional oil play—illustrate the size of the energy and economic prize . . . and the potential for future global carbon emissions.
- Given rapid innovation in hydrocarbon recovery and humanity's propensity to exploit available resources, "keeping it in the ground" looks like a risky climate strategy.



Source: Energy & Environmental Research Center

CO_2-Enhanced Oil Recovery: A Technical, Economic and Political Down Payment on Large-Scale Carbon Mitigation

- ***What if we instead aligned the global need to produce more energy and industry's interest in increasing hydrocarbon recovery with the imperative to reduce the carbon footprint of energy production?***
- Accelerating commercial deployment of carbon capture and storage (CCS) through the capture of CO_2 from power plants and industrial facilities for use in enhanced oil recovery (CO_2-EOR) can:
  - Deliver a triple-win of energy security, economic development and emissions reductions;
  - Further develop the technical capability and build out the infrastructure essential to long-term, large-scale carbon management.
  - Help build a political consensus on climate that can enable achievement of mid-century emissions reduction targets.

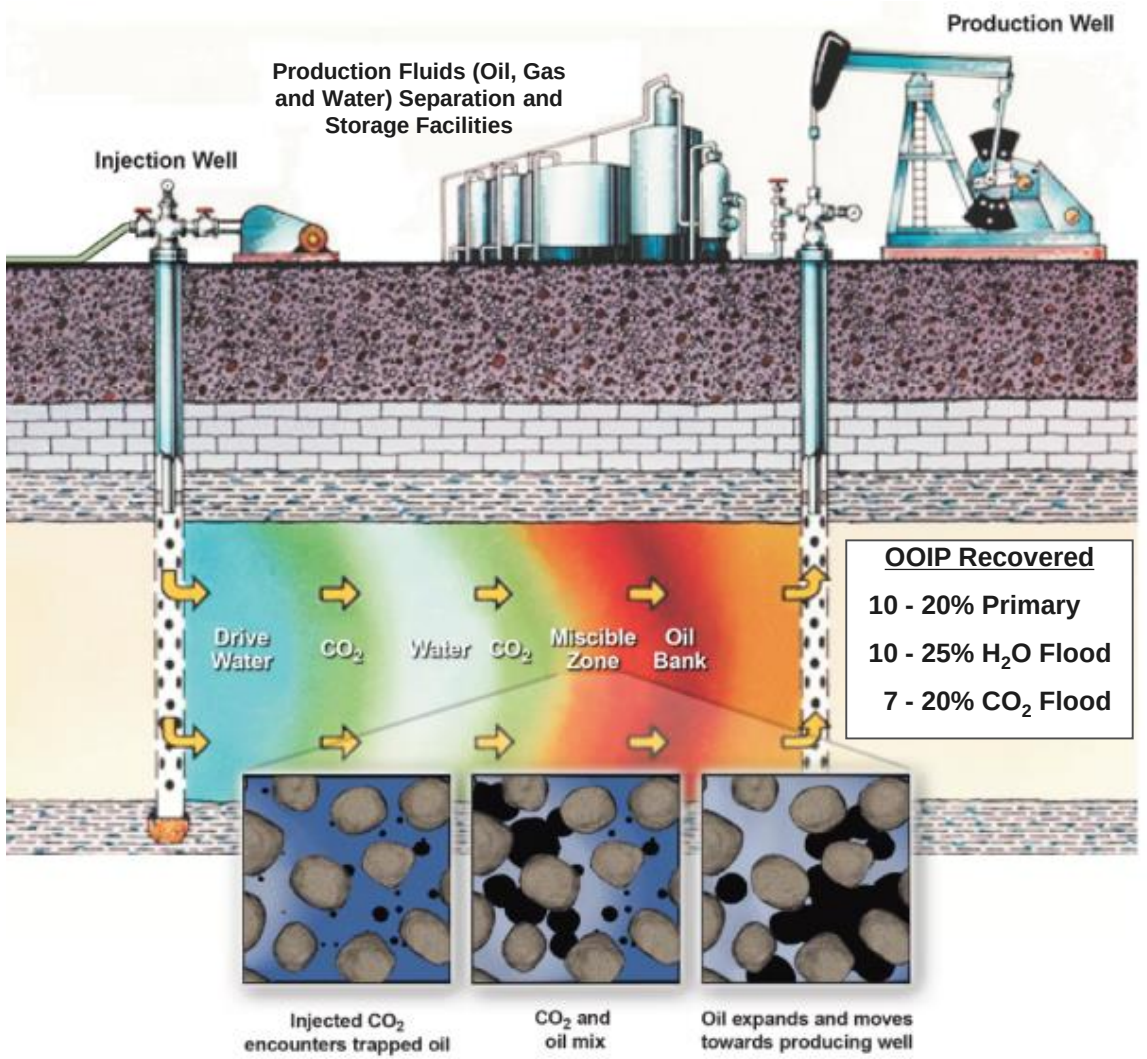
Carbon Capture and Storage is Essential to Achieving Mid-Century Carbon Reductions and Doing So Affordably

- Under the IEA's scenario to limit warming to 2° C, CCS contributes 14% of 2015-2050 CO_2 reductions.
- CCS is an essential control strategy for industrial sources, not just coal and natural gas power generation:
  - In IEA's 2° C scenario, 45% of CO_2 captured comes from industrial sources.
- The IPCC's 5th Assessment found the overall cost of carbon mitigation under the 2° C scenario to cost 138% more, if CCS was excluded.
- IEA concludes that renewables and efficiency alone simply cannot achieve the 2° C target.

How CO_2-EOR Works

Four Ways CO_2 Helps Recover Oil:

- Interfacial Tension Reduced:
  - Oil sticks less to rock
- Swelling of Oil:
  - Oil & CO_2 combine as a single phase, providing more efficient miscible displacement
- Improved Viscosity:
  - Viscosity of the combined miscible phase is reduced, allowing the fluid to be flushed to producers
- WAG Injection:
  - CO_2 is introduced in alternating cycles with H_2O
  - Provides greater sweep efficiency in the flood
  - Aids in controlling gas production



Source: DOE CO_2 EOR Primer, 2009

How Does Using CO_2 to Produce More Oil Actually Reduce Carbon Emissions?

- CO_2 captured, transported by pipeline and injected for EOR ultimately remains safely and permanently stored in the oil field, thus avoiding the power plant and industrial emissions that would otherwise occur.
- More CO_2 is injected than is emitted by the oil produced.
- Domestic oil produced through CO_2-EOR tends to displace oil we would otherwise import and consume.
- The U.S. tends to import heavier crudes that are more carbon intensive to refine than lighter crude produced through CO_2-EOR.
- The sale of CO_2 for use in oil production helps finance the build-out of carbon capture and pipeline infrastructure that can be used long term for CCS, even after oil production stops.

What is the Net Carbon Balance of CO2-EOR?

Life Cycle Analysis

- The California Center for Science and Technology (CCST) has the most comprehensive study to date – indicating a natural gas power plant with carbon capture for CO_2-EOR will show a **40% reduction** in emissions.
- The study examined California's "closed" system of carbon limits – which has the only policy framework that includes tailpipe emissions.
- In an "open" system without limits on end use petroleum emissions, reductions will depend on the sensitivity to price changes of future demand for oil.

Context of Scale

- 29.7 billion barrels of oil is the estimated production from injecting 13.5 billion tons of CO_2 for enhanced oil recovery, or roughly 100GW of CCS on coal plants over a twenty year period.
- This is slightly less than 2% of the world's proven oil reserves (IEA).
- And 1% of the world's estimated ultimate recoverable oil (USGS).

From a climate perspective, we should not forego using CO_2-EOR as a CCS pathway, just to avoid the incremental production of associated oil. Instead, we should rely on a more comprehensive technology-based strategy (e.g. zero carbon liquid fuels, electrification, etc.) to address petroleum emissions.

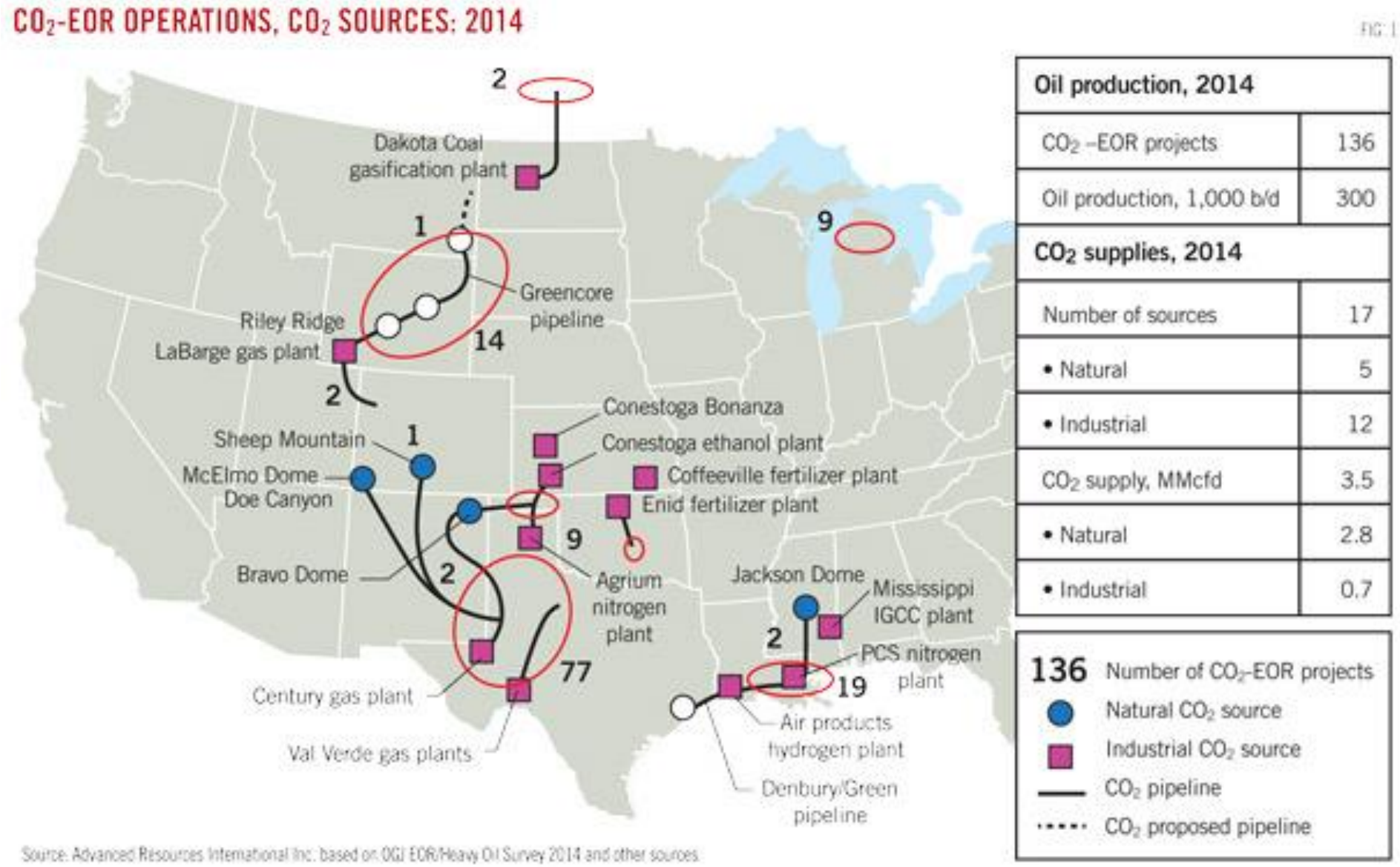
Source: Clean Air Task Force

Fortunately, CO_2-EOR is a Safe, Commercially Proven and Long-Standing CCS Pathway in the U.S.

- **Over 40 years experience**, beginning at significant scale in West Texas in 1972.
- Over **300,000 barrels of oil per day:**
  - 110 million barrels annually, or about 4 percent of U.S. domestic production.
- Over **4,500 miles of CO_2 pipelines**
- Over **67 million tons of CO_2 injected and stored each year.**
- **13 million tons of CO2 from man-made sources.**
- To date, more than **1.5 billion barrels of oil have been recovered** via CO_2-EOR.

Source: Melzer, 2012

Map of Current CO_2-EOR Activity and Infrastructure: Over 4,500 Miles of CO_2 Pipelines in U.S. Today

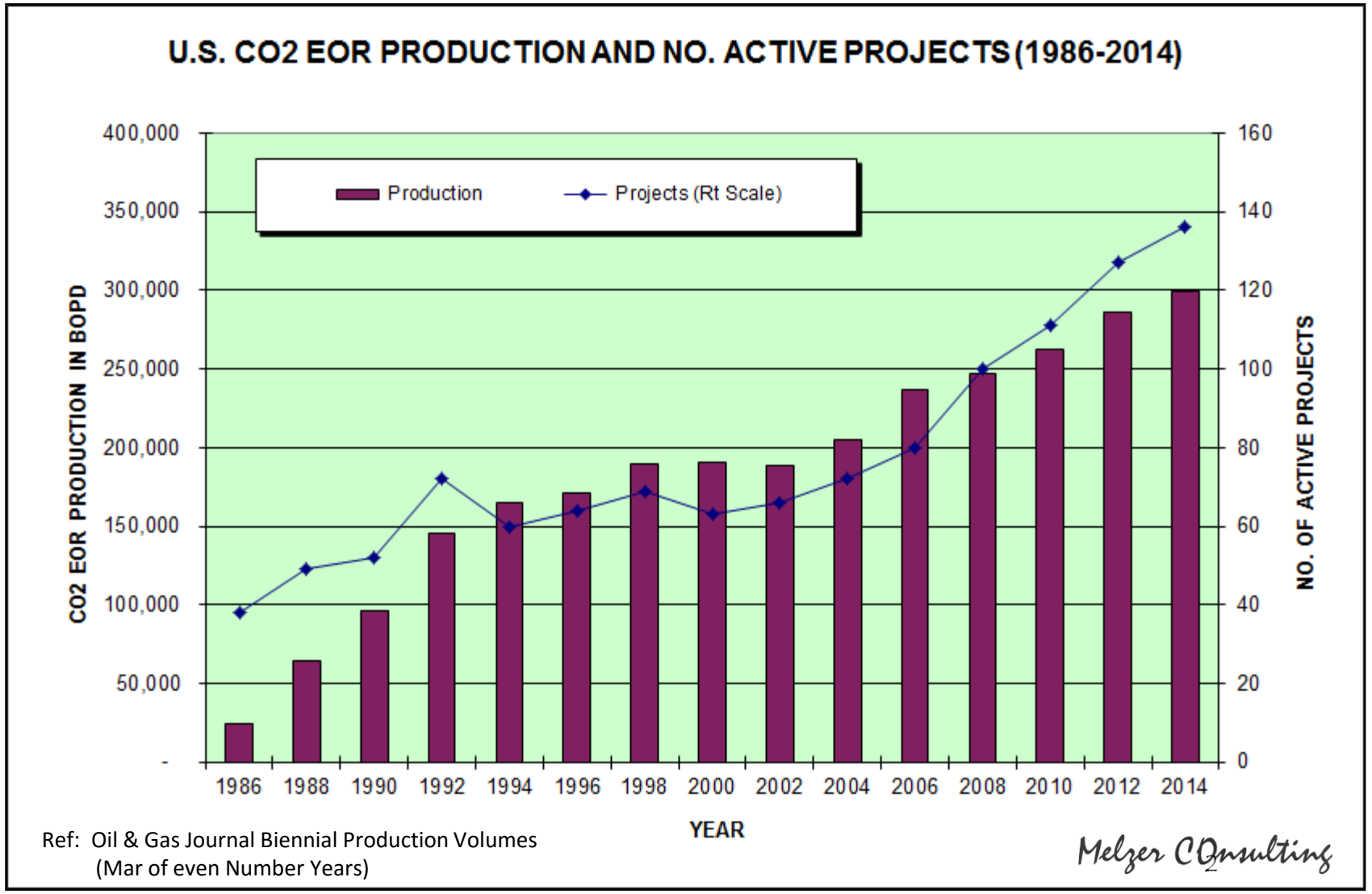


Oil production, 2014	
CO_2 –EOR projects	136
Oil production, 1,000 b/d	300
CO_2 supplies, 2014	
Number of sources	17
• Natural	5
• Industrial	12
CO_2 supply, MMcfd	3.5
• Natural	2.8
• Industrial	0.7

136 Number of CO_2-EOR projects
Natural CO_2 source
Industrial CO_2 source
CO_2 pipeline
CO_2 proposed pipeline

Source: Oil & Gas Journal, 2014, available at: http://www.ogj.com/content/dam/ogj/print-articles/volume-112/april-07/z140407OGJsku01.jpg

History of CO_2-EOR Production and Projects in US: Steady Growth Despite Oil Price Volatility



Ref: Oil & Gas Journal Biennial Production Volumes
(Mar of even Number Years)

CO_2-EOR is Not a Niche: Oil Production Potential is Vast

	Recoverable Resource (BBbls)*		Demand for CO_2 (Billion Metric Tons)		Average CO_2 Utilization (bbls/mtCO_2)	
	CBP*	Next Gen.	CBP*	Next Gen.	CBP*	Next Gen.
Technical	36.7	79.3	17.0	20.4	2.2	3.9
Economic**	21.4	63.3	8.9	16.2	2.4	3.9

* CBP – current best practices

** Economic assessment made based on oil price of $90 per barrel, CO_2 purchase cost of $40 per metric ton CO_2 at the field gate, and a 20 % rate of return (before tax) financial hurdle rate. Economic simulations are cut off when/if the annual operating revenues turns negative. The technical simulations are continued to the target injection amount (1.0 HCPV for CBP and 1.5 HCPV for "next generation").

- An additional 21.4-36.7 billion barrels of oil could be recovered with current best practices, potentially more than doubling current U.S. proven reserves.
- "Next generation" EOR technology could potentially increase recoverable domestic oil from EOR to 63.3 to 79.3 billion barrels, storing 16.2-20.4 billion metric tons of CO_2 that would otherwise be released into the atmosphere.

Source: Wallace, Kuuskraa, DiPietro., National Energy Technology Laboratory, *2013. "An In-depth Look at 'Next Generation' CO_2-EOR Technology"*
Available at: http://www.netl.doe.gov/energy-analyses/pubs/Disag%20Next%20Gen%20CO2%20EOR_full_v6.pdf

The Commercial Carbon Storage Potential is Also Vast

- According to Advanced Resources International, economically viable demand for CO_2 from conventional domestic oil fields is 9 billion metric tons of CO_2.
- Use of next generation technologies increases this to 26 billion metric tons of CO_2.
- This equals 40 years of CO_2 capture from 45 to 130 GWs of coal-fired power.
- At a CO_2 price of $36/mt, CO_2-EOR would provide a $300 to $900 billion revenue market to suppliers of CO_2.

CO_2 Demand: Current and "Next Generation" CO_2-EOR Technology

Resource Area	Demand for Purchased CO_2 (Billion Metric Tons)	
	Current Technology	Next Generation Technology
Lower-48, Onshore	9	21
Lower-48, Offshore	**	5
Total	**9**	**26**

*At oil prices of $80 to $90/B, CO2 costs of $36 to $40/mt and 20% ROR (before tax).
**Less than 0.5 Bmt.

Source: Advanced Resources International, 2016

Geologically Viable CO_2 Storage With By-Product Recovery of Oil!

San Andres ROZ "Fairway" Resource, Four-County Area of West Texas

County	CO_2 Storage		By-Product Oil Recovery	Purchased CO_2/ Oil Recovery Ratio		By-Product Net Revenues*
	(Tcf)	(B mt)	(B bbls)	(Mcf/Bbl)	(mt/Bbl)	($US, Billion)
Gaines	49	2.6	2.6	18.7	0.99	$158
Yoakum	20	1.1	1.3	15.7	0.83	$78
Terry	64	3.4	3.1	20.5	1.10	$192
Dawson	76	4.0	2.6	29.4	1.55	$157
Total	**209**	**11.1**	**9.6**	**21.7**	**1.16**	**$585**

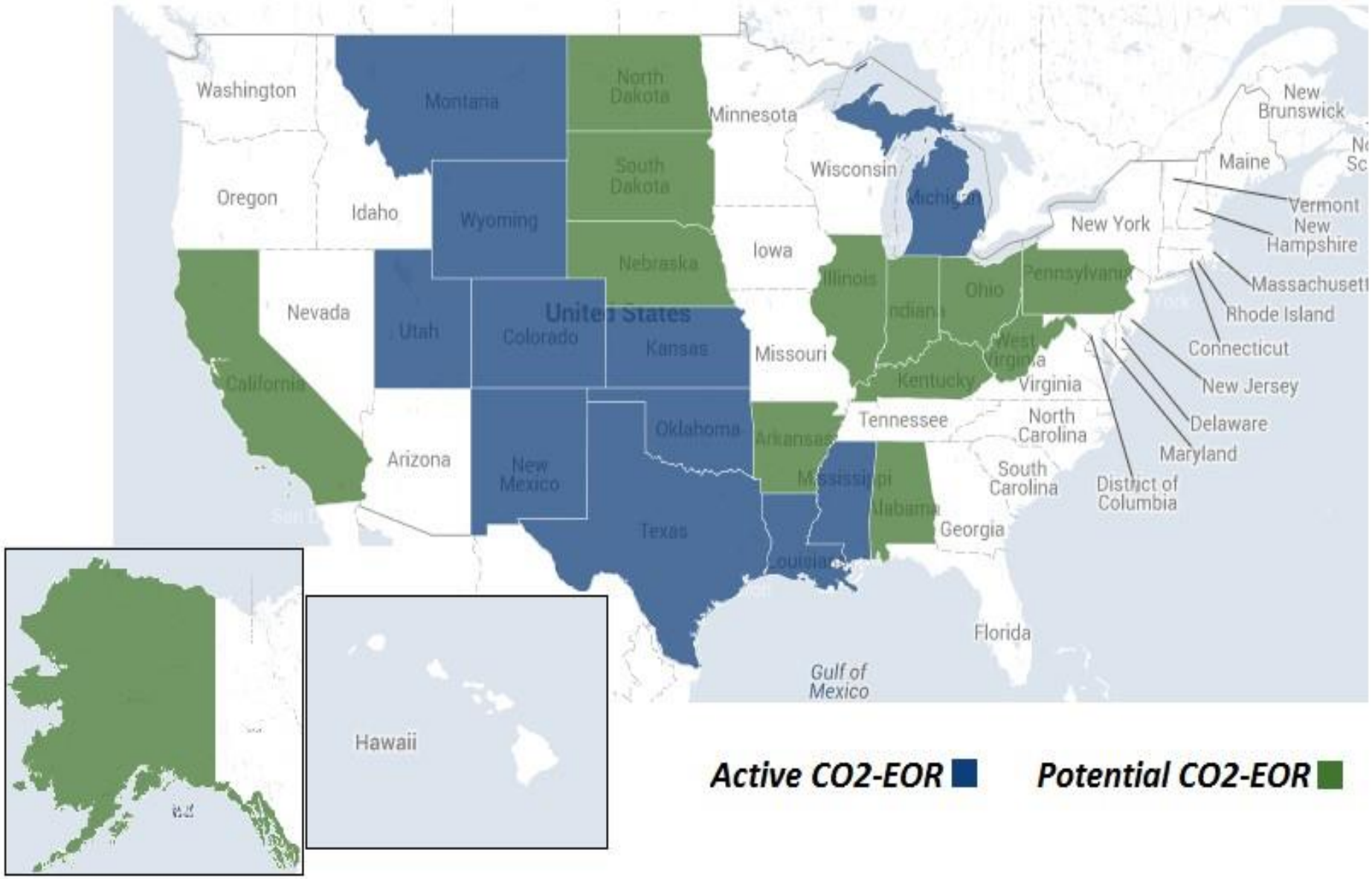
*At an $80 per barrel oil price, after excluding a net revenue interest of 80% and a 5% state severance tax.

The 9.6 billion barrels of by-product oil provides net revenues of $585 billion*, equal to $52/mt of CO_2 stored, **with the produced oil being highly carbon negative.**

Source: Advanced Resources International, 2015

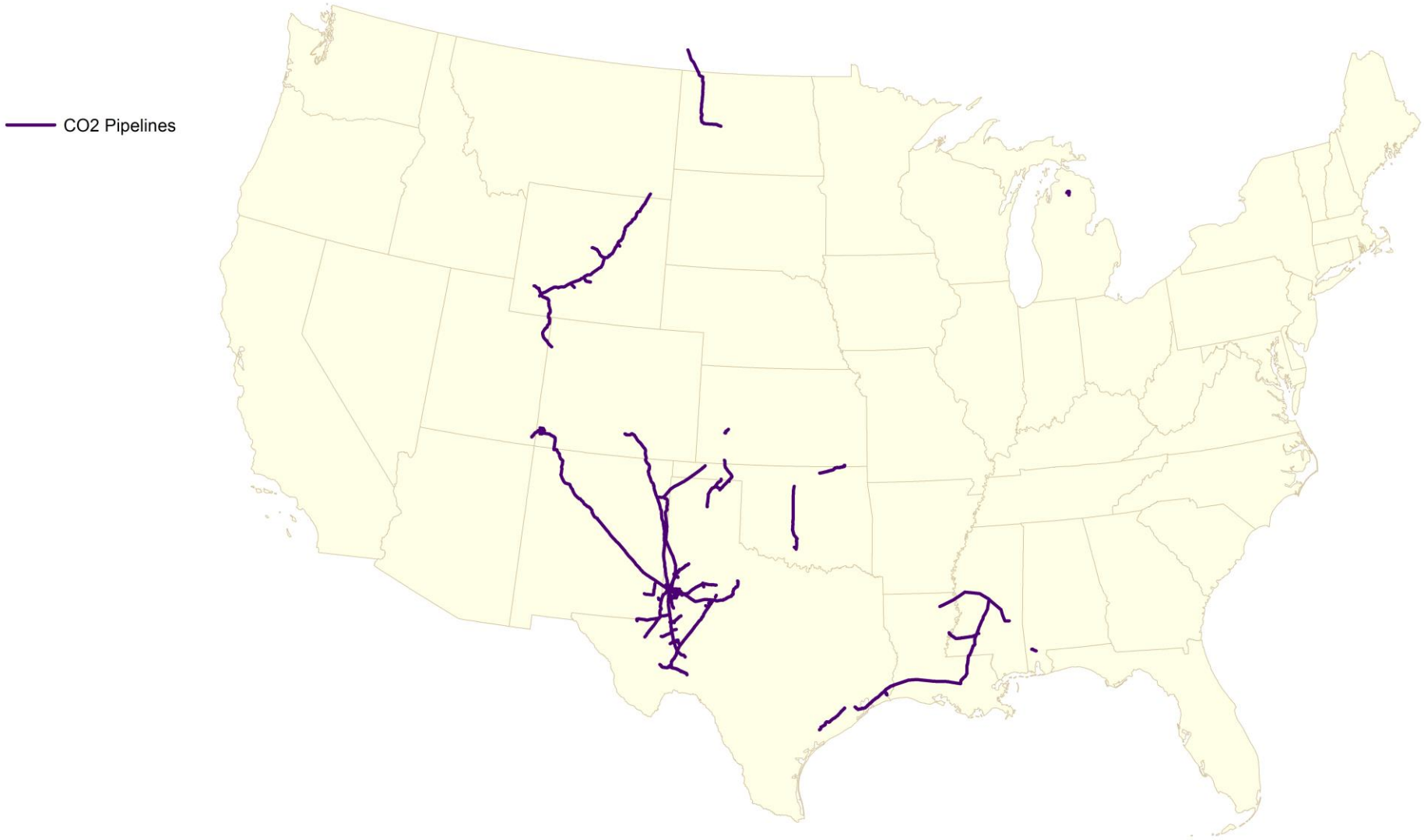
Preliminary

The Opportunity is National in Scope: Active and Potential CO_2-EOR States

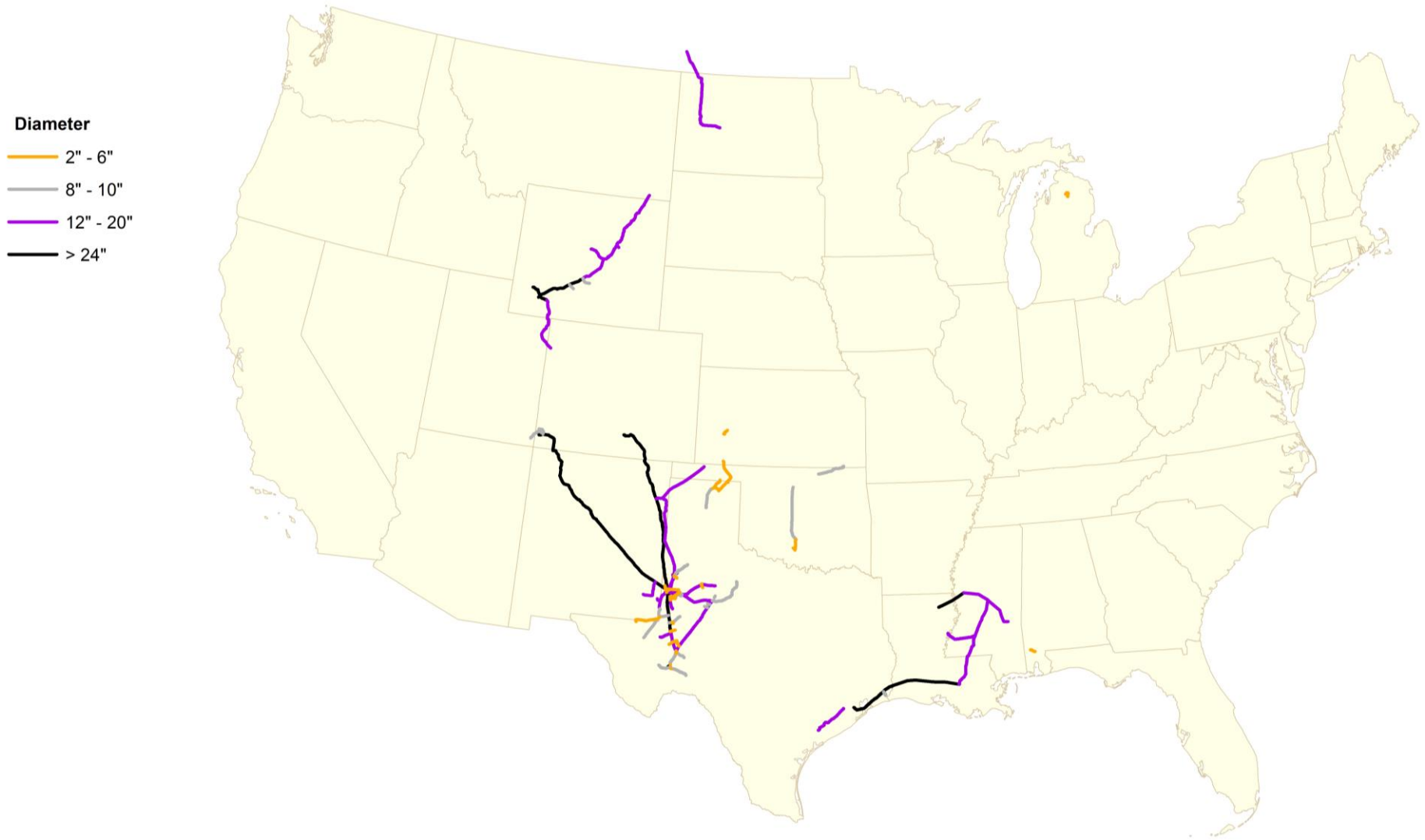


And Even More States Could Participate With the Development of a National CO_2 Pipeline Network . . . .

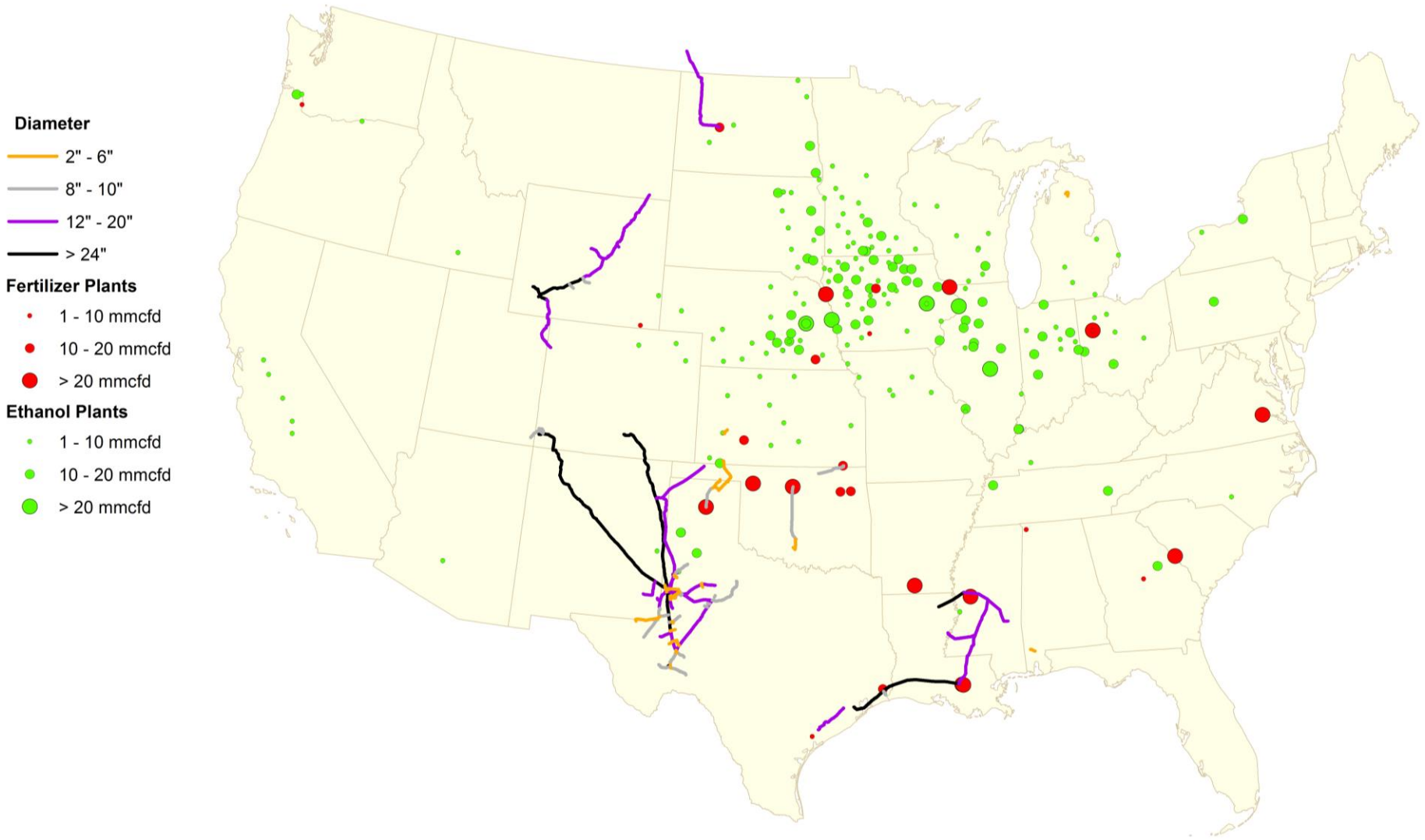
Current CO_2 Pipelines in the U.S.



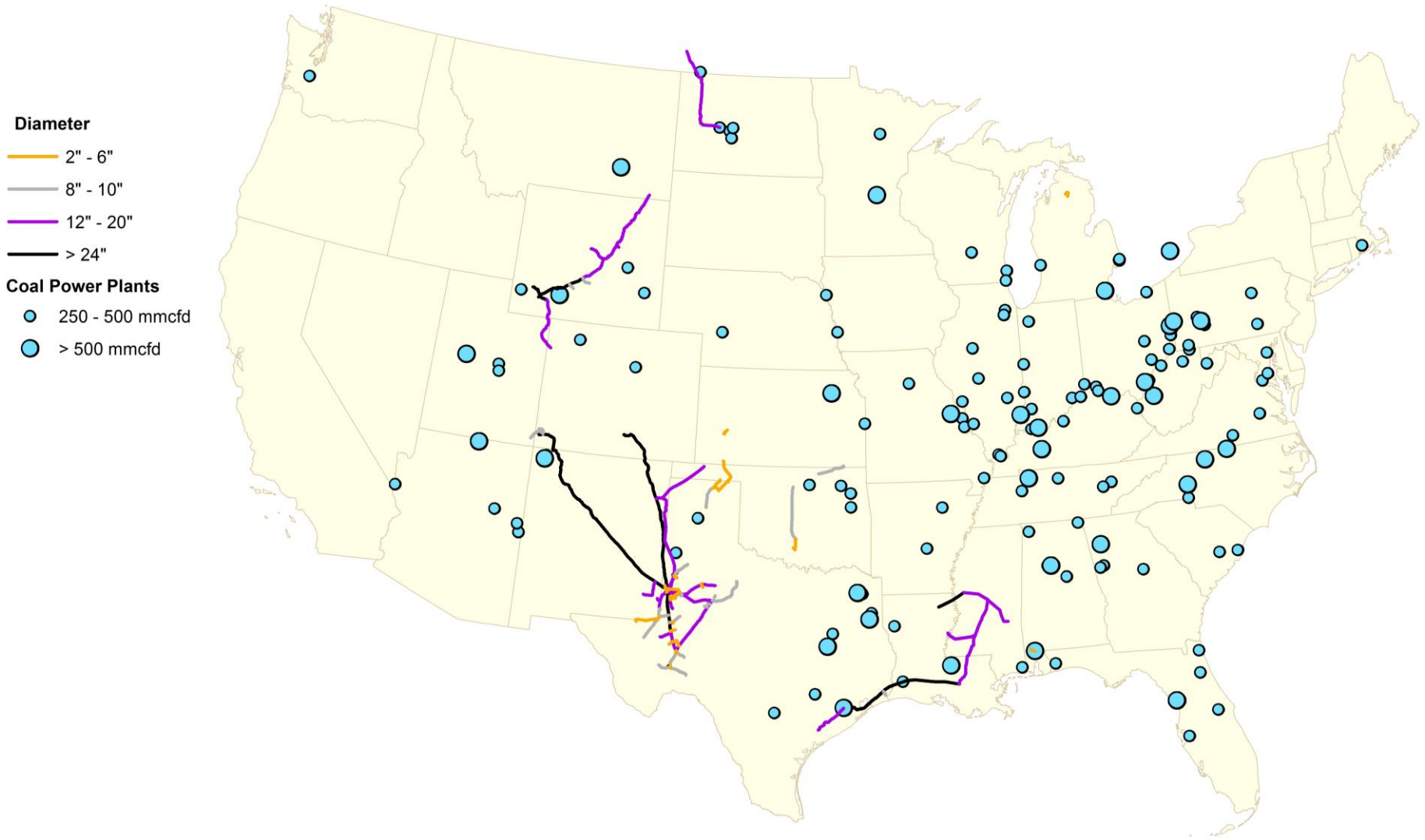
CO_2 Pipeline Capacity – by diameter



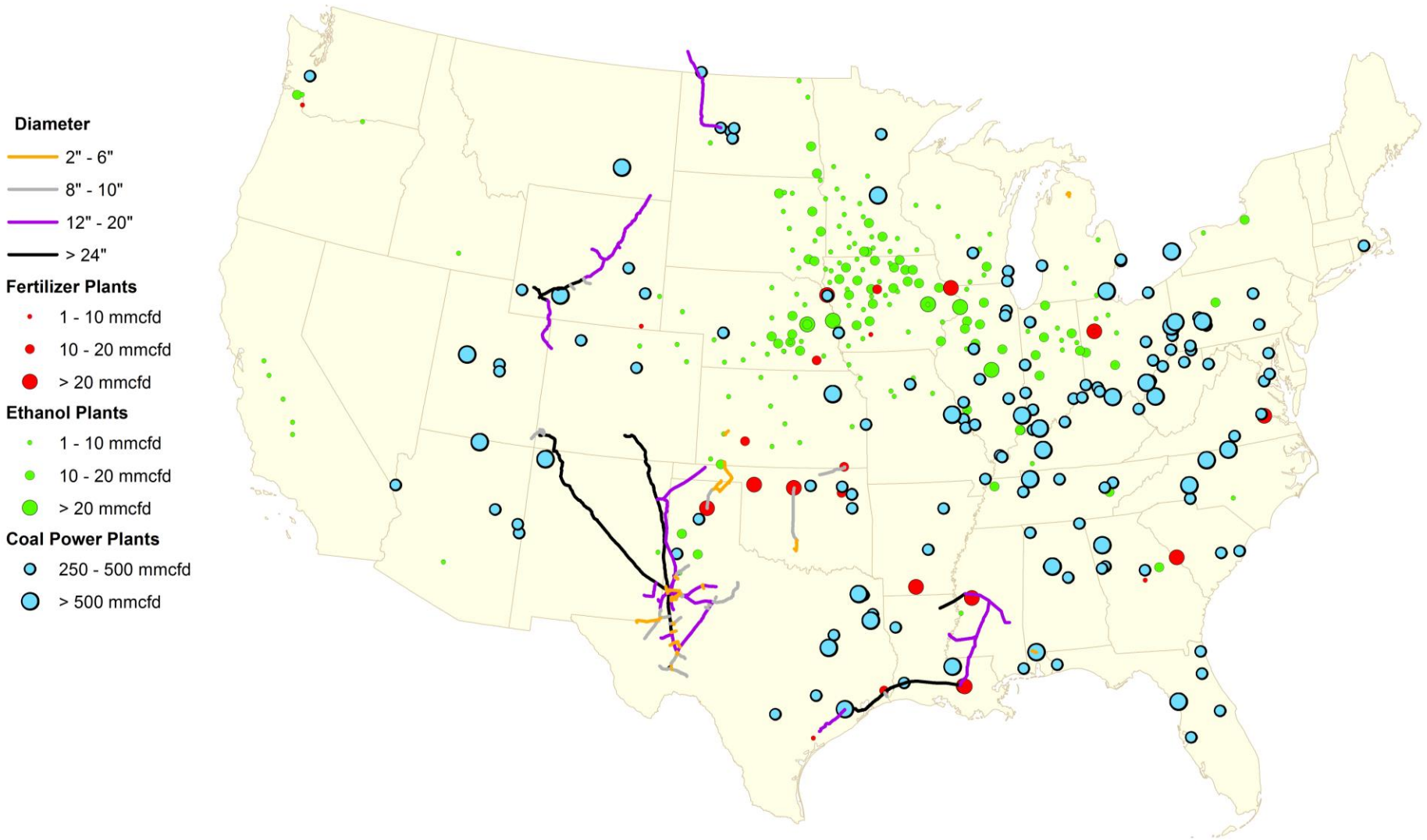
CO_2 Pipelines and Ethanol/Fertilizer Plants



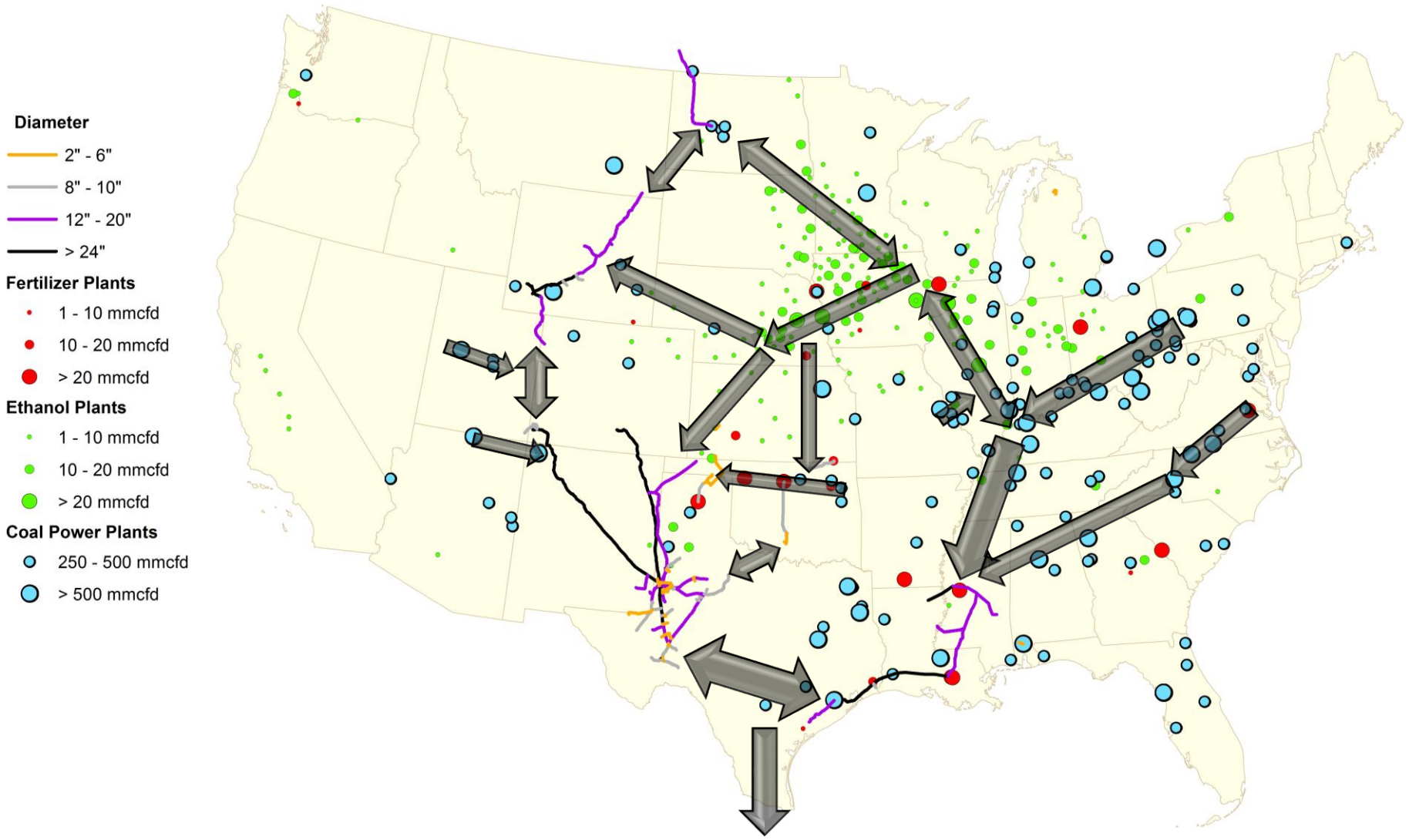
CO_2 Pipelines and Coal-Fired Power Plants



CO_2 Pipelines and Ethanol/Fertilizer/Coal Plants

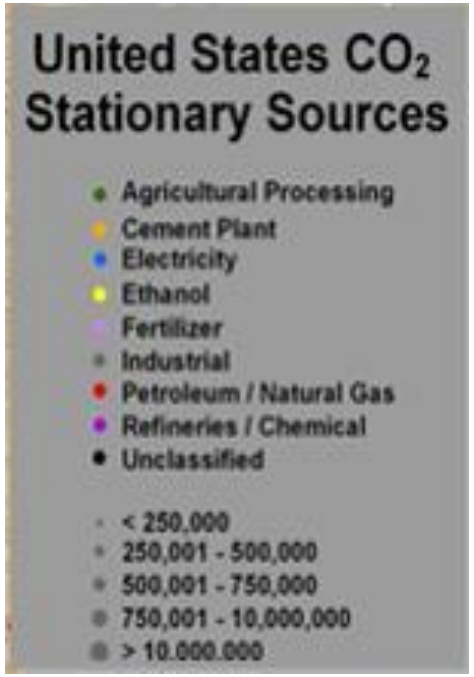


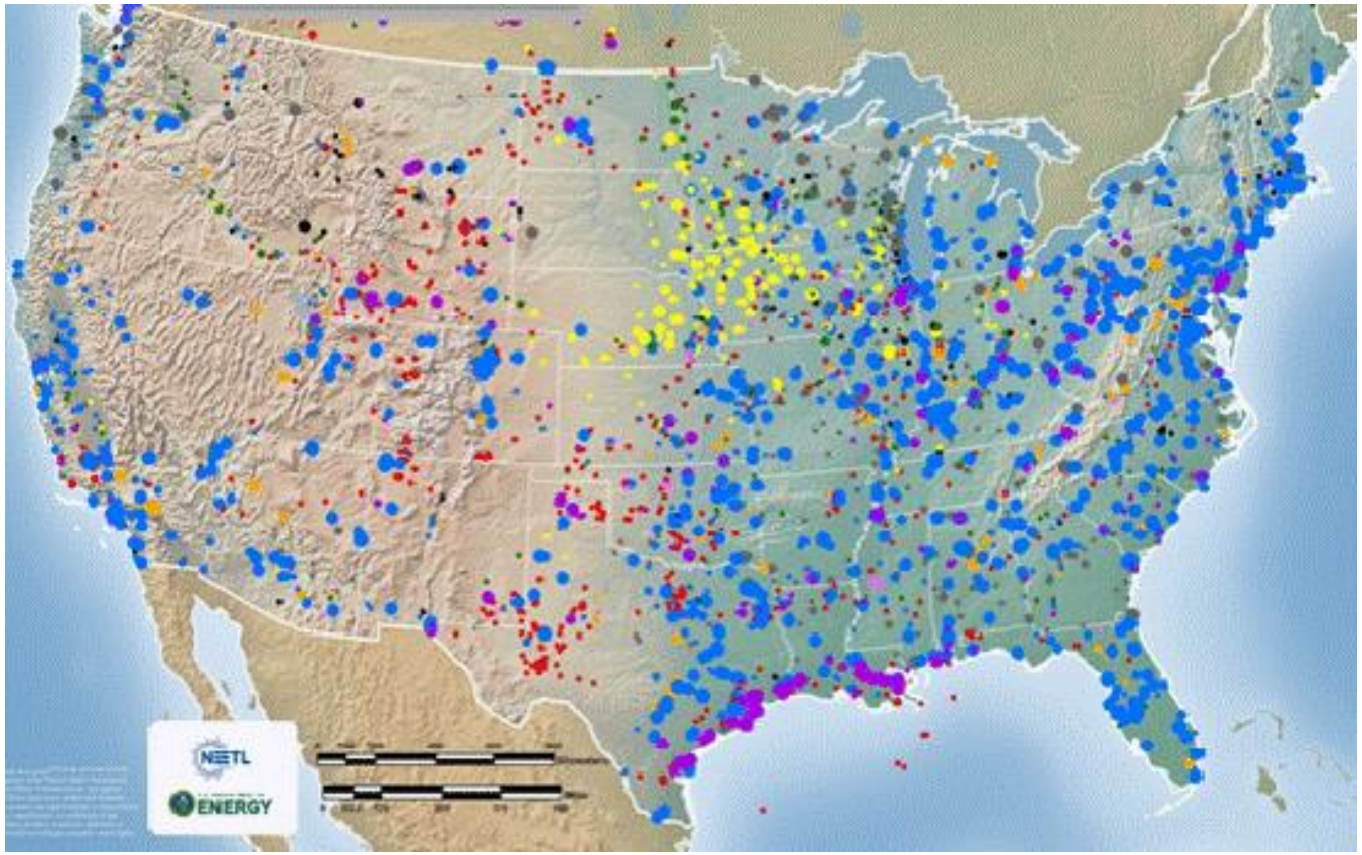
Possible Future CO_2 Pipeline Corridors



Realizing CO2-EOR's Full Potential Will Require More CO_2 from Power Plants and Industrial Facilities!

Map of Stationary CO_2 Sources in the U.S.





Source: National Energy Technology Laboratory, *2012 Carbon Sequestration Atlas of the United States and Canada - Fourth Edition (Atlas IV)*.

Commercial Scale CO_2 Capture has Occurred at Industrial Facilities for Years and Even Decades

Examples of commercial industrial CO2 capture for EOR and other geologic storage:

- Natural gas processing
- Fermentation of ethanol
- Fertilizer production
- Refinery hydrogen production
- Industrial gasification (non-IGCC)
- Steel production (just now being demonstrated in the UAE)

Air Products Steam Methane Reformer, Texas

Emirates Steel CCS Project, UAE

Commercial Scale Demonstration of CO2 Capture Underway in Power Sector, but Remains Costly and We Need More Projects

Texas Clean Energy Project

Kemper IGCC in LA

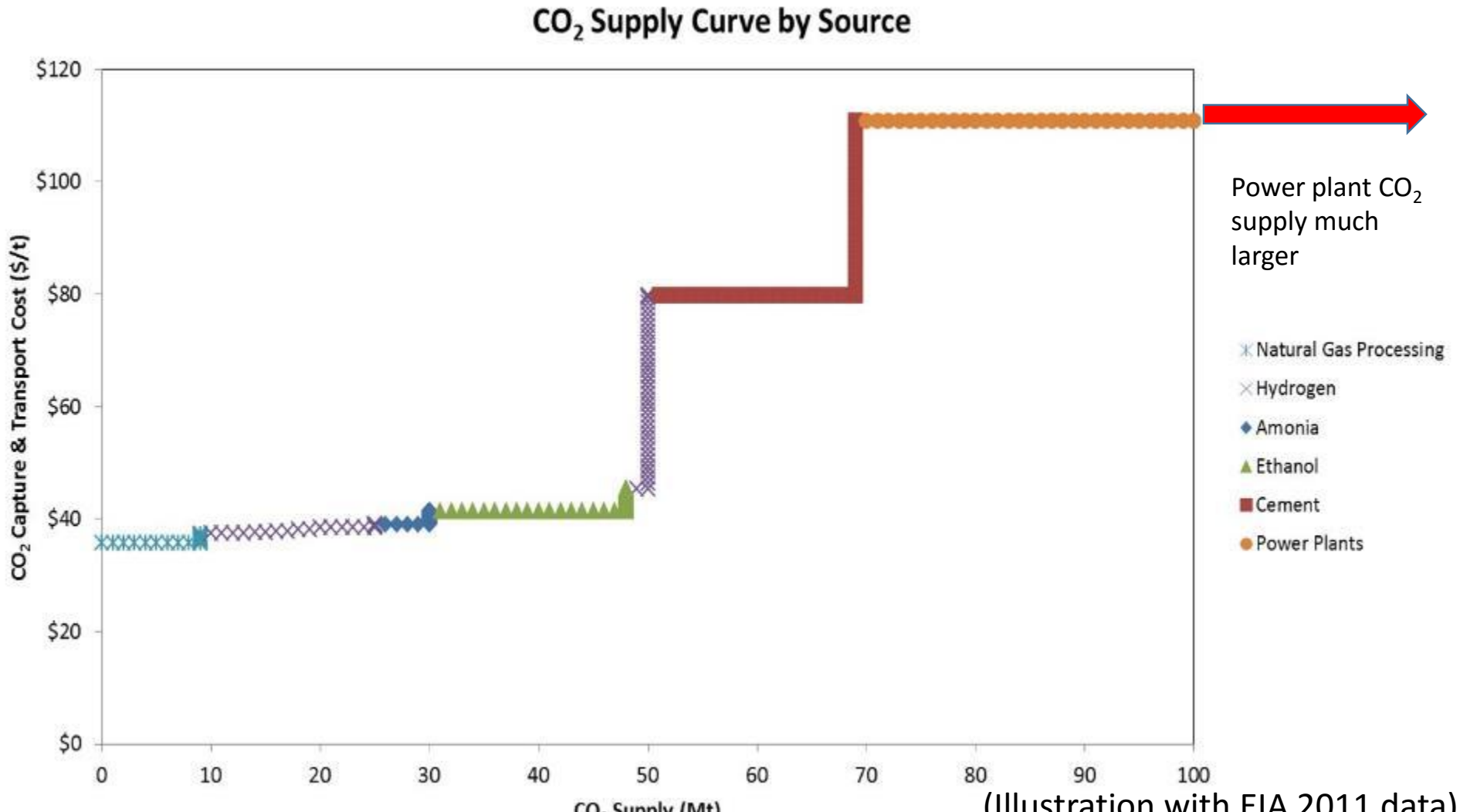
Boundary Dam Coal Retrofit in SK

Pre-Construction | Construction | Operation

NETPower Allam Cycle Nat. Gas. Demo in TX

Petra Nova Coal Retrofit in TX

Increasing the Supply of both Industrial and Power Plant CO_2 Will Require Financial Incentives to Drive Commercial Project Deployment and Reduce Costs of CO_2 Capture



(Illustration with EIA 2011 data)

The National Enhanced Oil Recovery Initiative (NEORI) Launched in 2011 to Support the Adoption of New CCS Incentives

NEORI Objectives:

1. ***Enact federal incentives to expand commercial deployment of CO_2 capture and pipeline transport*** from power plants and from gas processing, ethanol, fertilizer, chemicals, iron and steel, Portland cement, and other industrial facilities;
2. ***Encourage state policies to complement federal incentives*** and accelerate deployment;
3. ***Increase awareness of CO_2-EOR's economic and environmental benefits*** among policymakers, the media and public; and
4. ***Conduct analyses*** of the benefits of CO_2-EOR and understand the impacts of different incentive policies.

National Enhanced Oil Recovery Initiative

NEORI Participants: CO_2-EOR's Many Benefits Unite Diverse Fossil Energy, Labor & Environmental Interests

National Enhanced Oil Recovery Initiative

Coal Producers
- Arch Coal
- Cloud Peak Energy
- Peabody Energy

Electric Power Generators
- Great River Energy
- NRG Energy
- Summit Power Group
- Tenaska Energy

Industrial CO_2 Suppliers and Technology Vendors
- Air Products
- Alstom
- Archer Daniels Midland
- C12
- GE Oil & Gas
- Jupiter Oxygen
- LI-COR Biosciences
- Linde
- Praxair

Project Developers
- Lake Charles Methanol

Environmental NGOs
- Clean Air Task Force
- Natural Resources Defense Council
- Wyoming Outdoor Council

Labor Unions
- AFL-CIO
- International Brotherhood of Boilermakers
- International Brotherhood of Electrical Workers
- SMART Transportation Division
- United Mine Workers of America
- Utility Workers Union of America

Academic Institutions
- Enhanced Oil Recovery Institute (University of Wyoming)

Observers
- Chaparral Energy
- Core Energy
- Interstate Oil and Gas Compact Commission
- Mitsubishi Heavy Industries of North America
- Tellus Operating Group

Current U.S. Federal Policy for Deployment of Carbon Capture, Utilization and Storage is Uncertain and Insufficient

- Future prospects for federal grants and other direct financial support for further CCUS projects and technology demonstration are uncertain in the U.S.

- Concern over U.S. federal budget deficits and the national debt limits political support for such options.

National Enhanced Oil Recovery Initiative

The Existing U.S. Federal 45Q Tax Credit for Carbon Sequestration Illustrates the Problem

- The 45Q tax credit is valued at only $10 per ton of CO_2 captured and used in EOR—not enough for new capture projects, especially at current low oil prices.

- 45Q does not provide certainty for project developers and investors, who cannot plan projects with confidence that credits will be available:
  - The program is capped at 75 million tons of CO_2 and will likely run out in several years.

National Enhanced Oil Recovery Initiative

Reforming and Expanding U.S. Federal Incentives for CO_2 Capture and Transport Would Achieve Important Objectives

1. Cover remaining cost gap for new CCS projects:

- Cost gap = the cost of CO_2 capture, compression and pipeline transport *minus* revenue received from selling CO_2 to the oil industry for use in EOR.

2. Generate new revenue to the federal government from oil production to pay for the cost of the incentives:

- CO_2 captured with incentives ⟹ new oil production through EOR ⟹ new sales revenue and royalty income and payments ⟹ new tax revenue to the federal government to pay for incentives over time.

National Enhanced Oil Recovery Initiative

Proposed U.S. Federal Incentives Endorsed by NEORI

National Enhanced Oil Recovery Initiative

Key Goal:

- Reduce economic barriers to carbon capture and pipeline projects that sell CO_2 for use in EOR and result in permanent geologic storage.

Federal Incentive Options:

- Various incentives can address different economic needs of capture and pipeline projects, including:

Expand and reform existing US Section 45Q Federal Tax Credit for Carbon Sequestration (tax credit for every ton of CO_2 captured and stored through CO_2-EOR)

Authorize tax-exempt private activity bonds for CO_2 capture projects (allows for tax-free bonding of projects)

Authorize master limited partnerships for CO_2 capture projects (convey tax benefit of partnerships to capture projects)

Current State of Play on Federal Incentives

National Enhanced Oil Recovery Initiative

Expand and reform existing 45Q Tax Credit for Carbon Sequestration

- Improve existing production tax credit for EOR ($10/ton) and saline storage ($20/ton) and eliminate cap on number of credits
- House leader Mike Conaway (R-TX) has introduced the bipartisan Carbon Capture Act of 2016 with 20 co-sponsors, a version of which is being considered for inclusion by the Senate in broader tax legislation.

Authorize master limited partnerships (MLP) for carbon capture projects

- Would authorize tax-advantaged business structure for carbon capture projects that is already available for CO2 pipelines and EOR projects
- Bipartisan legislation introduced in 2015 in Senate by Moran (R-KS) and Coons (D-DE) and House by Poe (R-TX) and Thompson (D-CA)

Authorize private activity bonds (PABs) for carbon capture projects

- Would allow tax-exempt bonding long available for other pollution control technologies
- Bipartisan Senate legislation introduced last November by Portman (R-OH) and Bennet (D-CO)

Oil Price Stabilizations Mechanisms

- Amendment to pending Senate energy bill calls on DOE to propose a program to Congress allowing DOE to enter into multi-year contracts to purchase CO2 at a guaranteed price to reduce oil price risk for investors in CO2 capture projects (projects would pay DOE if oil prices exceeded the forecasted price)
- Bipartisan sponsorship from 10 senators.

President Obama's Tax Credit Proposal

- Investment and sequestration tax credits in President Obama's FY 2016 and 2017 budgets
- $10/ton for EOR storage over 20 years; $50/ton for saline
- Only power sector projects eligible

Conaway Carbon Capture Act 45Q Provisions

National Enhanced Oil Recovery Initiative

Make tax credit permanent, eliminating cap of 75 million tons of CO2

- Already 35 million tons claimed by 2014 per IRS
- Likely exhausted in several years, so credit is uncertain and fails to attract private investment in projects

Increase $/ton value for power plants and certain industrial sources

- From $10/ton for EOR storage to $20 and ramping up to $30 over 10 years; From $20/ton for non-EOR storage, ramping up to $30

Address lack of tax appetite for coops, munis and project developers

- Make 45Q transferable within chain of CO2 custody (renewables once had similar benefit)

Reduce project eligibility threshold

- Reduce current 500,000 ton capture threshold to 150,000 tons to enable participation of more industries with smaller CO2 sources (e.g. ethanol and fertilizer production) and important smaller scale commercial capture technology demonstrations)

Broad Political Support!

- 30 cosponsors (22 Republicans and 8 Democrats) from 21 states and spanning the ideological spectrum of Congress from the Freedom Caucus to the Congressional Black Caucus.

Coalition for 45Q Tax Credit Reform is Unprecedented and Highlights Potential for CO_2-EOR to Help Build Federal Energy Policy Consensus

National Enhanced Oil Recovery Initiative

- Companies and organizations that signed on to joint letters to House Ways and Means and Senate Finance in support of the Conaway 45Q legislation included:
  - Arch Coal, Cloud Peak Energy, and Peabody Energy (top five coal producers);
  - Occidental Petroleum (world's largest EOR operator);
  - ADM, Conestoga and White Energy (ethanol producers)
  - AFL-CIO, Utility Workers, United Mineworkers, and SMART Transportation (key industrial unions);
  - NRDC, Clean Air Task Force, C2ES, and Third Way (national NGOs); and
  - NEORI and Coal Utilization Research Council (leading coalitions supporting CCS).

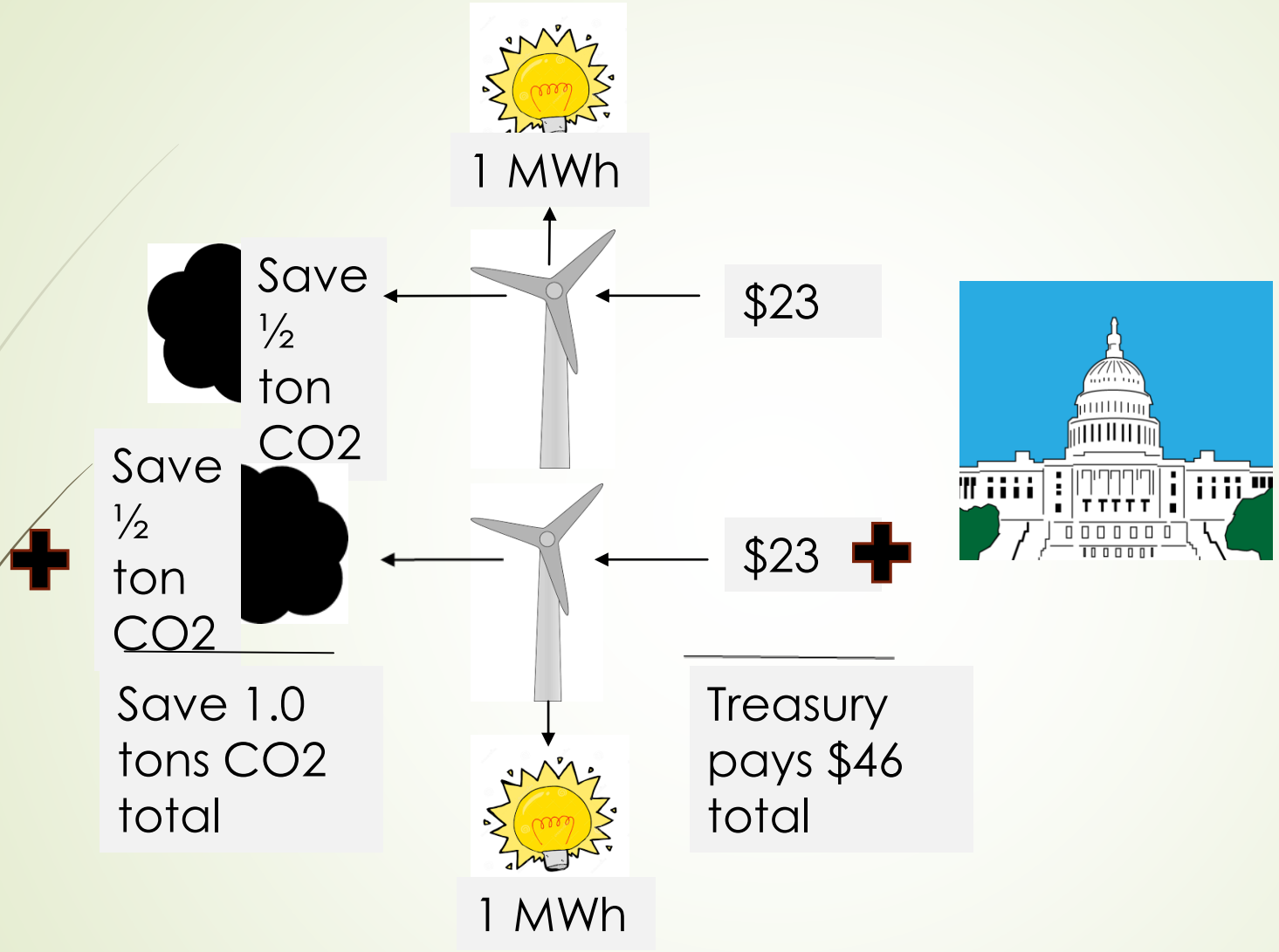
How Much Will this Cost? Not as Much as Commonly Understood, Even in the Power Sector

CCS incentives are competitive with renewables in electric power generation from a cost per ton of CO2 reduced/avoided basis—the most important metric from a climate perspective:

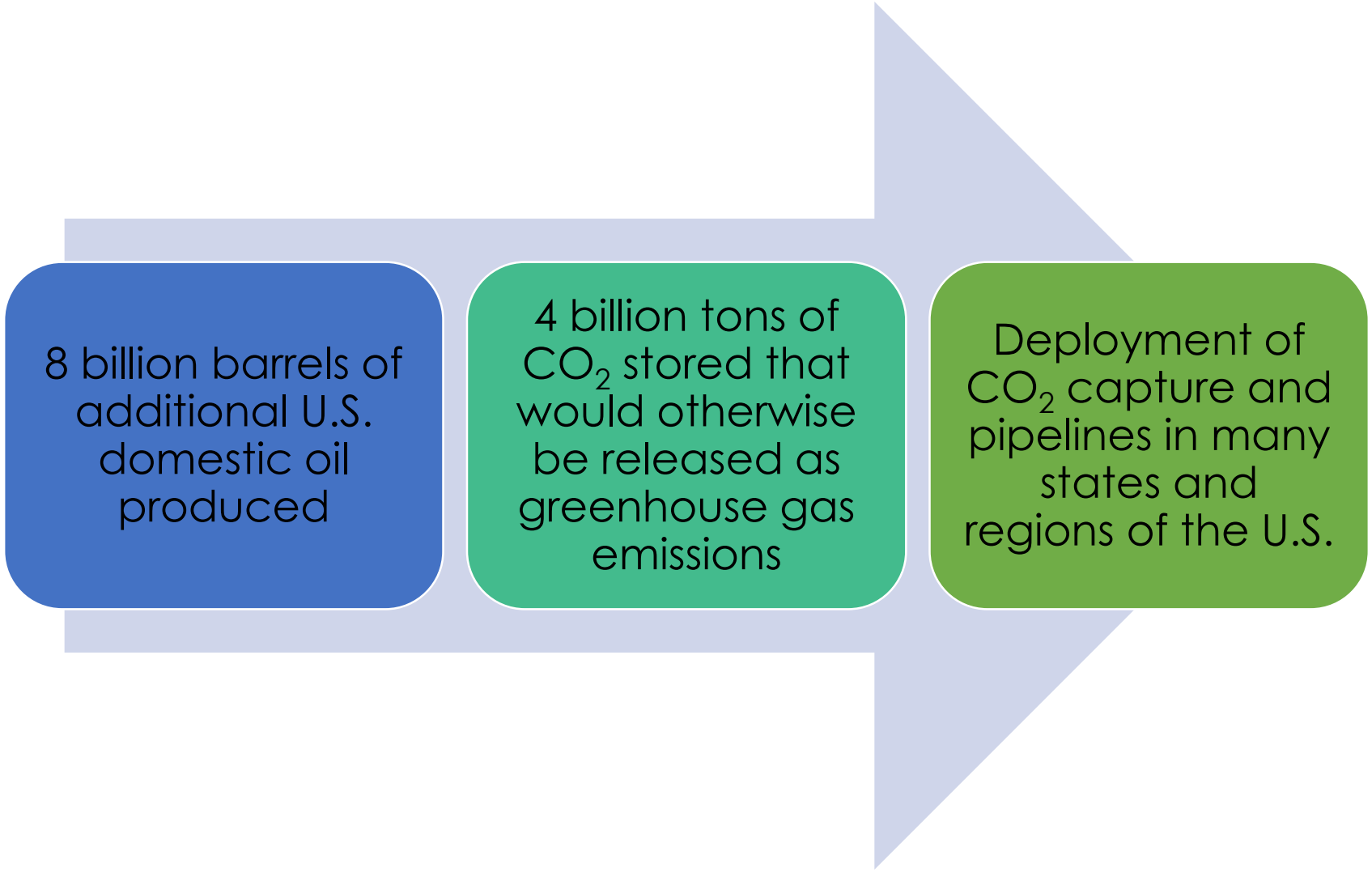
- NREL, in estimating impact of extending renewables tax credits concluded that one MWh of renewable power would displace a mix of 80% natural gas and 20% coal power.
- NREL Base Case weighted average CO2 savings: (80% gas x 0.4 tons/MWh) + (20% coal x 1.0 tons/MWh) = 0.52 tons CO2 saved per wind MWh
- This amounts to a cost for wind of $46/ton of CO2 avoided
- By contrast, $40-45/ton is commonly understood as a sufficient incentive for CCS deployment for coal-fired power generation (including revenues from sale of CO_2 for EOR).
- Schematic on the next page shows the NREL base case (with 0.52 tons rounded to ½ ton)

Source: Simplified presentation of analysis from Jeff Brown, Stanford University.

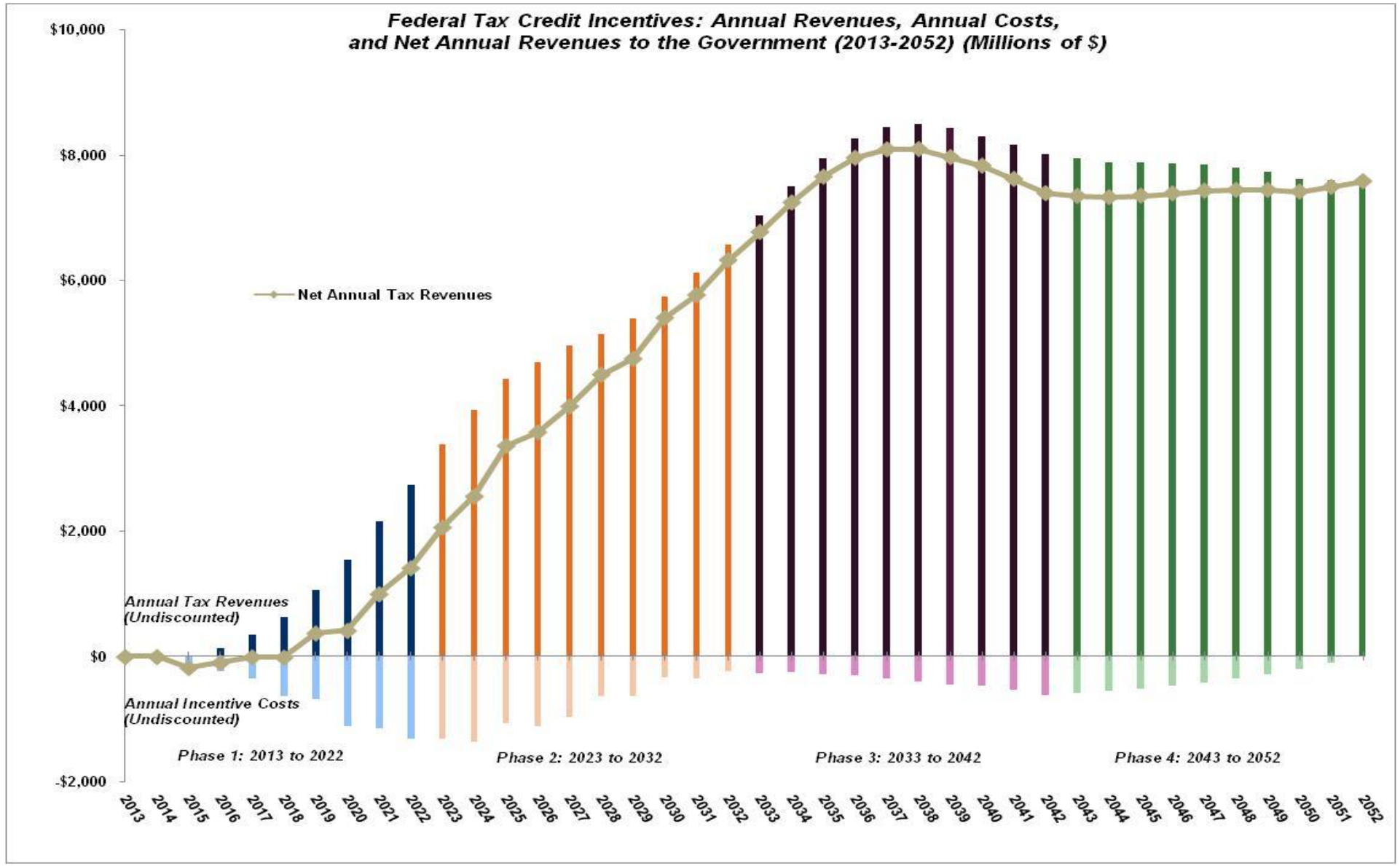
Costs $46 PTC to Save 1 ton with 2MWh



The Federal Revenue Argument is Even More Convincing: NEORI Analysis of the 2014 Rockefeller-Heitkamp 45Q Tax Credit Legislation Shows Significant Fiscal Benefits Over 40 Years



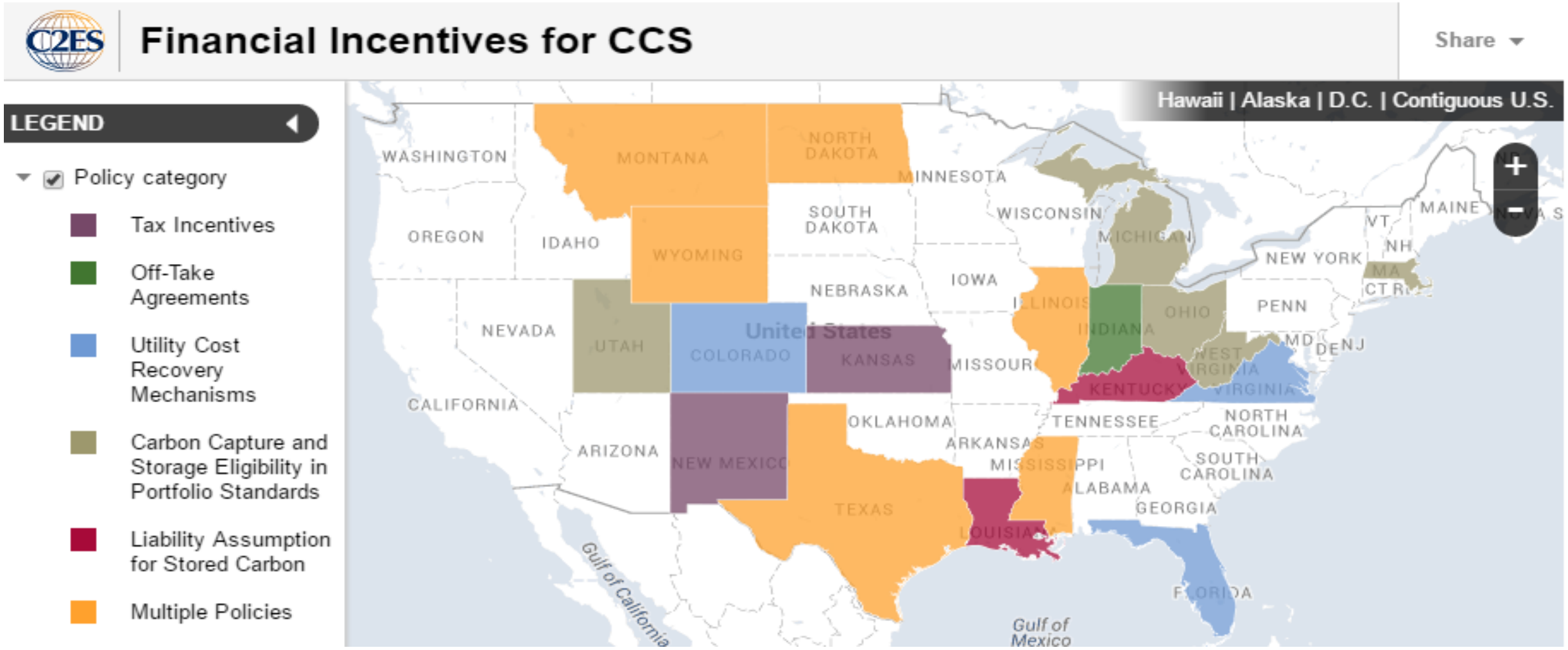
An Energy and Climate Solution That Pays for Itself: More Incentives = More CO_2 = More Oil Production = Federal Revenue That Exceeds the Cost of Incentives Over Time



And States Play an Important Role Too: State Tax and Other Policies Can Complement Federal Incentives to Support Commercial Project Deployment

- NEORI has identified the following policies that state can and have adopted to complement federal incentive policies:
  - Tax credits, exemptions, or abatements for CO_2 capture;
  - Severance tax reductions for oil produced via CO_2-EOR;
  - Regulatory cost recovery approval for carbon capture projects (especially for regulated electric utilities);
  - Off-take agreements to provide a guaranteed customer and price for a CCUS project;
  - State-level bonding of CO_2 pipeline projects and/or capture and compression facilities; and
  - Inclusion of CO_2 capture with EOR in electricity portfolio standards that require a certain percentage of electricity be generated from renewable and low-carbon sources.

Nearly 20 States Have Adopted Some Form of CCS Incentive



And States Are Now Engaging at the Leadership Level and Joining the Chorus in Support of Federal CCS Incentives

Over the past year, governors and other state officials have endorsed three resolutions calling on Congress to enact federal CCS incentives: Western Governors Association, Southern States Energy Board and National Association of Regulatory Utility Commissioners.

In September, Governor Matt Mead (R-WY) and Governor Steve Bullock (D-MT) co-convened a State CO_2-EOR Deployment Work Group of governors' staff and state officials and private sector stakeholders from 14 oil and gas and coal-producing states that is developing recommendations on federal and state CCS-EOR incentives policy and will work to support their implementation.

THANK YOU

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